Final Report for AFOSR Grant
Theory and Algorithms for Global/Local Design Optimization
2-11-2001 to 31-12-2004

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Abstract: This is the final report on AFOSR grant F49620-02-1-0070. The research was motivated by aircraft structural design problems where the overall (global) design of the structure need to be coordinated with the design of components (local). The research focused on improved methods for decomposition, for coordinating the component and overall design as well as on exploration of global optimization algorithms. In the former category, heuristic decomposition was followed with proof that it solves the original problem. In the latter category, stochastic algorithms (genetic algorithms and particle swarm optimization) were explored as well as the DIRECT deterministic global algorithm. Part of the research was done in collaboration with researchers at Virginia Tech who were funded under AFOSR grant F49620-02-1-0090.

Introduction: Aircraft and spacecraft structural design operates at several scale levels. There is the overall design of the entire vehicle, the design of major components such as wings, the design of smaller components, such as stiffened panels, and detail design, such as reinforcements near small holes. It is not possible to carry on the structural design optimization at all levels simultaneously, because the number of design variables and the complexity of the analysis would make the problem computationally intractable. Therefore, aerospace structural designers tend to iterate between the levels. They design at one scale, obtain forces on components on a scale below and use them to design at the lower scale. This process does not need to converge, and if it does converge, it does not need to converge to the optimum design. The research described below was motivated by input from designers from Boeing and McDonnell Douglas who alerted us to the difficulties they were experiencing.

The research focused on improved methods for decomposition, for coordinating the component and overall design as well as on exploration of global optimization algorithms. In the former category, heuristic decomposition was followed with proof that it solves the original problem. In the latter category, stochastic algorithms (genetic algorithms and particle swarm optimization) were explored as well as the DIRECT deterministic global algorithm. Part of the research was done in collaboration with researchers at Virginia Tech who were funded under AFOSR grant F49620-02-1-0090.

Description of research results

Decomposition: Heuristic decomposition algorithms were developed for coordinating the structural design of aircraft wings (Refs. 6-8, 10, 22). These were verified against results

REPORT DOCUMENTATION PAGE

AFRL-SR-AR-TR-05-

0334

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT T\
		fINAL REPORT

4. TITLE AND SUBTITLE
Theory and Algorithms for Global/Local Design Optimization

5. FUNDING NUMBERS
F49620-02-1-0070

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8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Air Force Office of Scientific Research
875 North Randolph Street
Suite 325, Room 3112
Arlington, VA 22203 NM

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION AVAILABILITY STATEMENT
Approved for public release,
distribution unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*
This is the final report on AFOSR grant F49620-02-1-007O. The research was motivated by aircraft structural design problems where the overall (global) design of the structure need to be coordinated with the design of components (local). The research focused on improved methods for decomposition, for coordinating the component and overall design as well as on exploration of global optimization algorithms. In the former category, heuristic decomposition was followed with proof that it solves the original problem. In the latter category, stochastic algorithms (genetic algorithms and particle swarm optimization) were explored as well as the DIRECT deterministic global algorithm. Part of the research was done in collaboration with researchers at Virginia Tech who were funded under AFOSR grant F49620-02-1-009O.

14. SUBJECT TERMS

15. NUMBER OF PAGES

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT

at a single level (Ref. 6), and then they were generalized to a decomposition approach where at upper level budgets are assigned for the component designer, and at the lower level the component designer maximizes constraint satisfaction. References 4 and 5 developed the mathematical framework for the approach, showing that it is equivalent to the single level formulation. Furthermore, it was demonstrated by simple examples in Refs. 4 and 5 and by engineering examples in Refs. 23, 24 and 27, that the decomposition approach allows for more efficient global optimization then a single-level approach. Decomposition approaches were also examined for optimization used for system identification in bio-motion, specifically the identification of human joint parameters from records of motion (Ref.s. 11, 25, and 27).

Global optimization algorithms: Our initial focus was on genetic algorithms. A permutation genetic algorithm, needed for two-level wing design was developed (Ref. 21). Later the focus shifted to two other stochastic global optimization algorithms. The first type was statistical optimization using estimated probability distribution of good design points (Refs.2,3, 14-20). This included the development of an improved statistical algorithm that combined statistical information from two different models of the design problem (Refs. 3, 17, 20). The second global optimization algorithm was particle swarm optimization in the context of application to bio-motion system identification (Refs. 11-13, 25-28). Here we also explored the opportunities to parallelize the algorithm (Ref. 12). Finally, the deterministic DIRECT algorithm was also examined as an alternative for global optimization (Ref. 1).

Students: The grant supported three PhD students. Boyang Liu, who finished his PhD in 2001 and stayed on as a research associate for several months after that. H is working for The ABAQUS software company in Providence, RI. employed. Laurent Grosset, finished his PhD in 2004 with a joint PhD degree from UF and the University of St. Etienne in France and is now working for Renault, Paris France. Jaco Schutte is scheduled to finish his PhD at the end of 2005.

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